

DIRECT CURRENT MOTOR USING MAGNETS WITH EXTENSIONS

CROSS REFERENCE TO RELATED APPLICATION

The present application relates to and incorporates
5 herein by reference Japanese Patent Applications No. 11-142042
filed on May 21, 1999, No. 11-203769 filed on July 16, 1999
and No. 11-270566 filed on September 24, 1999.

BACKGROUND OF THE INVENTION

10 The present invention relates to direct current motors
having permanent magnets.

A conventional direct current (d.c.) motor 20 is
comprised of permanent magnets 21 and 22, an armature 23, a
commutator 24, brushes 25 and the like as shown in Figs. 13A
15 to 13C. In this motor, the armature 23 rotates as shown in the
order of Figs. 13A, 13B and 13C, when direct current power is
supplied thereto.

Specifically, the armature 23 has an armature core 26
and armature coils 27. A plurality of teeth 26a is formed on
20 the core 26. Each coil 27 is wound around five teeth 26a,
although only one is shown in the figures. The coils 27 are
wound in a distributed winding form.

The commutator 24 has a plurality of segments 24a on which
the brushes 25 slide, so that the direct current flows from the
25 brushes 25 to the coils 27 through the segments 24a of the
commutator 24. Thus, the armature 23 rotates in the clockwise
direction (arrow X) in the figures, as the direction of current

flowing in the coils 27 is reversed.

The current supplied to the coil 27 from the brush 25 is changed as shown in Figs. 14A to 14C. It is assumed that the current I flows from right to left as shown in Fig. 14A, and that the commutator 24 moves to the right as shown in Fig. 14B relative to the brush 15 as the armature 23 rotates. The brush 25 bridges two adjacent segments 24a to supply the coil 27 with shorting current i. The current I flows from the left to the right in the coil 27 as shown in Fig. 14C, as the armature 23 rotates further. That is, the direction of the current I flowing in the coil 27 is reversed, when the armature 23 rotates as shown in the order of Figs. 14A, 14B and 14C. In this instance, the current which changes by 2I from +I to -I is supplied from the brush 25.

Figs. 14A to 14C corresponds to Figs. 13A to 13C. When the armature 23 rotates as shown in the order of Figs. 13A, 13B and 13C, the direction of current I in the coil 27 is reversed. The direction of the magnetic field in the core 26 wound with the core coil 27 is reversed. The rotating force is generated to rotate the armature 23 by the electromagnetic force of the coils 27 and the magnetic force of the magnets 21 and 22.

The reversion of current flowing in the coil 27 during the period of shorting by the brush 25 is defined as commutation. This relation is expressed in the following commutation equation.

$$L(di/dt) + e + Rci + R2(I+i) - R1(I-i) = 0$$

In the above equation, $L(di/dt)$ is a reactance voltage

generated by an inductance of the coil 27 shorted by the brush 25, and e is an induction voltage generated in the coil 27 when the armature 23 rotates. R_c is a resistance of the coil 27 shorted by the brush 25. R_1 and R_2 are contact resistances between the brush 25 and the commutator 24. I is a current supplied from the brush 25, and i is a shorting current of the coil 27 shorted by the brush 25.

The shorting current i changes linearly as shown by the dotted line in Fig. 15, as long as the reactance voltage $L(di/dt)$ of the coil 27 and the induction voltage e is negligible during the commutation period. In this instance, the commutation is effected linearly and most favorable.

However, the reactance voltage and the induction voltage are generated in the coil 27 in fact. The shorting current i therefore flows with a delay in time relative to the linear commutation characteristics as shown by the solid line in Fig. 15, resulting in an insufficient commutation. This insufficient commutation causes spark discharges at the rear end of the brush 25, when the commutation terminates. The spark discharges causes noise and brush wear.

It is proposed to counter this problem, that is, improve the commutation operation by moving the brush in the counter-clockwise direction in Fig. 13. The brush is moved to reduce the influence of the induction voltage e . Specifically, the induction voltage e is generated as a counter-electromotive force in the coil 27 by changes in the magnetic flux amount Φ passing through the coil 27. This voltage e is expressed

as follows.

$$e = - d\Phi/dt$$

That is, the induction voltage e is generated in proportion to the speed of reduction in the magnetic flux amount Φ passing through the coil 27.

The induction voltage e is shown in Fig. 16. Specifically, Fig. 16 shows changes in the magnetic flux amount Φ passing through the coil 27 and hence passing through the core 26 (five teeth 26a) around which the coil 27 is wound, and the induction voltage e generated in the coil 27 in response to the change in the magnetic flux amount Φ . In Fig. 16, the magnetic flux amount Φ and the induction voltage e are shown with respect to a reference position (0°) which corresponds to Fig. 13B. That is, the reference position is defined as the position where the center of the core 26 (five teeth 26a) wound with the coil 27 coincides with the center of the magnet 21 or 22.

When no current flows in the coil 27, only the magnetic flux of the permanent magnets 21 and 22 passes through the coil 27. In this instance, the magnetic flux amount Φ is maximal when the rotation position of the armature 23 is at the reference position (Fig. 13B) as shown by (A) in Fig. 16.

When the current flows in the coil 27, however, it generates the magnetic force which influence the magnetic flux of the magnets 21 and 22. As a result, the magnetic flux amount Φ of the coil 27 changes with the rotation position of the armature 23 as shown by (B) in Fig. 16, because the current

is reversed during the commutation period, that is, when the armature 23 rotates as shown in the order of Figs. 13A, 13B and 13C. That is, the magnetic flux amount Φ changes from positive to negative, when the armature 23 passes through the reference position. As a result, the magnetic flux amount Φ which actually passes through the coil 27 changes as shown by (C) in Fig. 16. This amount is a sum of the flux amounts indicated by (A) and (B). Thus, the actual magnetic flux amount Φ becomes maximum before the armature 23 rotates to the reference position. As a result, the induction voltage e of the coil 27 changes from negative to positive when the total magnetic flux amount becomes the maximum. For this reason, the induction voltage e is generated in a manner to delay the commutation and delay the reversion of the shorting current i , causing the insufficient commutation.

Therefore, the influence of the induction voltage e in the coil 27 is minimized by moving the position of the brush 25 in the direction opposite the rotation of the armature 23, that is, in the counter-clockwise direction in Fig. 13. In practice, the position of the brush 25 is determined based on not only the induction voltage but also the reactance voltage.

It is however difficult to maintain good commutation operation, because the current flowing in the coil 27 and the rotation speed of the motor change from time to time. For instance, in the case of a blower motor used for an automotive air conditioner unit, the position where the total magnetic flux amount Φ attains the maximum moves to a position (negative

side in Fig. 16) opposite the rotation direction at high load and high rotation speed conditions because more current is supplied. The induction voltage e caused by the total magnetic flux amount Φ also increases as the rotation speed increases. Further, the reactance voltage also increases as the current in the coil 27 increases. Thus, the brush need be moved more for good commutation operation. In the case of low load and low speed conditions, on the contrary, the brush need be moved less for good commutation operation. It is thus required to move the brush position from time to time.

SUMMARY OF THE INVENTION

The present invention therefore has an object to provide a direct current motor capable of attaining good commutation operation irrespective of loads.

According to the present invention, a direct current motor is comprised of an armature having a core and coils wound on the core, magnets arranged to face each other through the armature, a commutator operatively connected to the coils, and a brush for shorting each coil during a commutation period to reverse a direction of current in the coil. Each magnet has an extension at a circumferential end thereof to generate in the coil an induction voltage which counteracts to the reactance voltage. A commutation characteristics is improved to be sufficiently linearized. Preferably, the magnet has, at the extension, a varying thickness or magnetic pole orientation strength different from that of its main part. A visible member

is provided on the axial end of the magnet.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, features and advantages of the present invention will become more apparent from the following detailed description made with reference to the accompanying drawings.

In the drawings:

Fig. 1 is a schematic sectional view showing a direct current motor according to a first embodiment of the present invention;

Fig. 2 is a schematic diagram showing a relation between a magnet and an armature in the first embodiment;

Fig. 3 is a graph showing magnetic flux amount and induction voltage relative to armature rotation positions in the first embodiment;

Fig. 4 is a schematic diagram showing a relation between the magnet and the armature in a second embodiment of the present invention;

Fig. 5 is a graph showing magnetic flux amount and induction voltage relative to armature rotation positions in the second embodiment;

Fig. 6 is a graph showing commutation characteristics;

Fig. 7 is a schematic diagram showing a relation between the magnet and the armature in a third embodiment of the present invention;

Fig. 8 is a schematic diagram showing a relation between the magnet and the armature in a fourth embodiment of the present invention;

Fig. 9 is a schematic view showing the magnet used in a fifth embodiment of the present invention;

Fig. 10 is a schematic view showing the magnet used in a sixth embodiment of the present invention;

Fig. 11 is a perspective view showing the magnet used in a seventh embodiment of the present invention;

Fig. 12 is a perspective view showing the magnet used in an eighth embodiment of the present invention;

Figs. 13A to 13C are schematic sectional views showing a conventional direct current motor;

Figs. 14A to 14C are schematic diagrams showing commutation operation of the conventional motor;

Fig. 15 is a graph showing commutation characteristics of the conventional motor;

Fig. 16 is a graph showing magnetic flux amount and induction voltage relative to armature rotation positions in the conventional motor.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention will be described in detail with reference to various embodiments in which a direct current motor is designed as a blower motor for an automotive air conditioner unit. In the air conditioner unit, the current supplied to the motor is variably determined by a manual switch. Specifically, 18 amperes current and 4 amperes current are supplied to the motor when the manual switch is manipulated to a HI-position (high output) and LO-position (low output), respectively. The

current determines the rotation speed of the motor and hence the amount of air supplied into the air conditioner unit.

(First Embodiment)

Referring first to Fig. 1, a blower motor 1 is comprised of magnets 2 and 3, an armature 4, a commutator 5, brushes 6 and the like. The motor 1 is a two-pole direct motor. The magnets 2 and 3 which provide N-pole and S-pole are arranged around the armature 4 to face each other in a housing 7. The armature 4 has an armature core 8 and armature coils 9 wound around the core 8. The armature 4 rotates when the coils 9 are supplied with direct current. The core 8 is formed with a plurality of (twelve) teeth 8a. Each tooth 8a is spaced apart 30° in the circumferential direction from adjacent teeth. Although only one coil is shown in the figure, each coil 5 is wound on separate five of teeth 8a in the distributed winding form.

The commutator 5 is disposed at one axial side end of the core 8 and is comprised of a plurality of segments (commutator pieces) 5a. The brushes 6 are biased to slidably contact the commutator 5. The direct current is supplied from a direct current power source to flow from the brush 6 to the coil 9 through the segments 5a of the commutator 5. Thus, the armature 4 rotates in the clockwise direction (arrow X) in the figure, as the direction of current flowing in the coils 9 is reversed. In this embodiment, the direction of the current is reversed every 30° rotation of the armature 4 relative to the brush 6, because each segment 5a is provided every 30° in the

circumferential direction. That is, the commutation of coils is effected every 30° rotation of the armature 4.

The magnets 2 and 3 have main magnetic pole parts 2a and 3a and extensions 2b and 3b, respectively. The main parts 2a and 3a correspond to the magnets 21 and 22 of the conventional motor (Fig. 13), respectively. The extensions 2b and 3b are provided at forward positions in the rotation direction, that is, at positions where each tooth 8a passes after passing the main parts 2a and 2b, respectively.

In Fig. 2, the magnet 2 is shown as straightened although it is in an arcuate shape. Further, the circumferential width of the magnet 2 is indicated in terms of angle and the core 8 (five teeth 8a) is shown to have 150° ($30^\circ \times 5$). As understood from Figs. 1 and 2, each main part 2a, 3a has a circumferential length which corresponds to the angular interval (120°) between the centers of the first and fifth teeth of five teeth 8a around which each coil 9 is wound. The center of commutation is defined as the rotation position of the armature 4 where the center of the main part of each magnet and the center (third teeth) of the five teeth 8a align as shown in Fig. 1. The direction of current of the coil 9 shorted by the brushes 6 is reversed at this position.

Each extension 2b, 3b is gradually thickened over the 30° angular interval from the end of the main part 2a, 3a in the rotation direction of the armature 4. It is gradually thinned over the 5° angular interval from the thickest part in the rotation direction of the armature 4. This 5° angular

interval is not limitative but may be more or less, as long as the motor 1 produces a maximum performance.

Referring further to Fig. 2, the positional relation between magnet 2 and the core 8 (five teeth 8a) wound with the coil 9 is described with respect to the commutation period.

The commutation starts when the core 8 rotates to the position, where the top end of the core 8 align the thinned part 2c of the magnet 2 as shown by (a) in the figure. When the core 8 rotates 15° further as shown by (b), the core 8 reaches the center of commutation shown in Fig. 1. The direction of current is reversed at this position. The commutation ends, when the core 8 further rotates 15° and reaches the position shown by (c) in Fig. 2. That is, the commutation of coil 9 is effected during the angular interval 30° in the order of positions (a), (b) and (c). The extension 2b is gradually thickened during this commutation period of angular interval 30° .

The magnetic flux amount Φ passing through the coil 9 under commutation is shown in Fig. 3. In this figure, the reference position 0° indicates the rotation position of the armature 4 shown in Fig. 1 in which the center of the core 8 (five teeth 8a) wound with the coil 9 and the center of the main part 2a, 3a align. As shown in Fig. 3, the magnetic flux amount Φ increases gradually as the armature 4 rotates. The rate of change in the magnetic flux amount Φ increases as the rotation speed of the armature 4 increases. The magnetic flux amount Φ indicates a sum of the magnetic flux generated by the

current flowing in the coil 9 and the magnetic flux amount generated by the magnets 2 and 3. The dotted line in Fig. 3 shows the magnetic flux amount generated in the conventional motor and shown by (C) in Fig. 16.

5 Further, as shown in Fig. 3, the induction voltage e generated in the coil 9 is small during an initial period of commutation and gradually increases in the negative side as the armature 4 rotates. This induction voltage e counteracts to the reactance voltage and improves the insufficient
10 commutation shown in Fig. 15. That is, the commutation characteristics is linearized as shown by the dotted line in Fig. 15 by generating the induction voltage e which completely corresponds to the reactance voltage. In the case that the load of the motor 1 is changed by the manual switch of the air
15 conditioner, the current supplied to the coil 9 changes and the reactance voltage responsively increases and decreases. In this instance, however, the induction voltage e changes to counteract the reactance voltage in accordance with the motor load.

20 Specifically, the reactance voltage increases in accordance with the current of the coil 9, when the manual switch is manipulated to the HI-position to increase the current of the coil 9 to 18 amperes. In this instance, the motor rotation speed increases and the induction voltage e also increases.
25 The reactance voltage decreases in accordance with the current of the coil 9, when the manual switch is manipulated to the LO-position to decrease the current to 9 amperes. In this

instance, the motor rotation speed decreases and the induction voltage e also decreases. Thus, although the reactance voltage changes with the motor load, the induction voltage e also changes to cancel out the reactance voltage. As a result, good commutation can be effected even when the motor load changes.

As described above, according to the first embodiment, the induction voltage is generated counteract the reactance voltage in accordance with the motor load without moving the brush. Specifically, the commutation characteristics is linearized. As a result, the brush sparks can be restricted, resulting in the reduction of noise and brush wear. Thus, good commutation can be maintained irrespective of changes in the motor load. As the motor 1 can be operated stably, the air conditioner unit can be operated appropriately with the appropriate rotary driving force. As the brush sparks are restricted, special measures for noises caused by the sparks are not necessitated. The commutation performance can be improved with ease by changing the shape of the magnets 2 and 3.

(Second Embodiment)

In the second embodiment, each magnet 2, 3 shown in Figs. 1 and 2 are replaced with a magnet 11 shown in Fig. 4. The magnet 11 is shown as straightened form in this figure, although it is actually in an arcuate shape.

As shown in Fig. 4, the magnet 11 has a main part 11a and an extension 11b extended from one end of the main part 11a in the direction of rotation of the core 8. The extension

11b has a circumferential length which corresponds to an angular interval of 30°. It is gradually thinned in the direction of rotation of the core 8. The main part 11 has the other end 11c which is gradually thinned in the direction opposite the direction of rotation of the core 8. The rate of thinning relative to the circumferential length is less at the end 11b than at the extension 11c.

The magnetic flux amount Φ passing through the coil 9 increases as shown in Fig. 5 during the commutation period in which the core 8 rotates in the order of (a), (b) and (c). The rate of increase in the magnetic flux amount Φ relative to the rotation of the armature 4 is maximum at the initial period of commutation, and gradually decreases with the rotation of the armature 4. As a result, the induction voltage e generated in the coil 9 is maximum in the negative side at the initial period of commutation, and reaches 0 at the end of the commutation period after gradually increasing from the negative maximum. This induction voltage e also cancels out the reactance voltage. That is, as shown in Fig. 6, the commutation characteristics is improved as shown by the solid line relative to the insufficient commutation shown by the one-dot chain line. This characteristics is sufficiently close to the most desired commutation characteristics shown by the dotted line.

The above second embodiment also provides the same advantages as the first embodiment. Further, the magnet 11 can be produced with ease because it needs be thinned simply at

its circumferential ends.

(Third Embodiment)

In the third embodiment, a magnet 12 arcuate in shape is formed with extensions 12b and 12c at both circumferential ends of a main part 12a as shown in Fig. 7. Each extension 12b, 12c has a circumferential length which corresponds to the angular interval of 30° for commutation. The extension 12b has the same uniform thickness as the main part 12a, while the extension 12c is thinned gradually in the direction opposite the direction of rotation of the core 8. In this embodiment also, the magnetic flux amount Φ changes in the similar manner as shown in Fig. 5 during the commutation period in which the core 8 rotates in the order of (a), (b) and (c). The reactance voltage is cancelled out by the induction voltage e generated by changes in the magnetic flux amount Φ , and the commutation characteristics is improved as shown by the solid line in Fig. 6.

(Fourth Embodiment)

In the fourth embodiment, a magnet 13 arcuate in shape is formed with extensions 13b and 13c at both circumferential ends of a main part 13a as shown in Fig. 8. Each extension 13b, 13c has a circumferential width which corresponds to the angular interval of 30° for commutation. The extension 13b is gradually thinned in the direction of rotation of the core 8, while the extension 13c has a uniform thickness less than that of the core 8. In this embodiment also, the magnetic flux amount

Φ changes in the similar manner as shown in Fig. 5 during the commutation period in which the core 8 rotates in the order of (a), (b) and (c). The reactance voltage is cancelled out by the induction voltage e generated by changes in the magnetic flux amount Φ , and the commutation characteristics is improved as shown by the solid line in Fig. 6.

(Fifth Embodiment)

In the fifth embodiment, a magnet 14 arcuate in shape is formed to have the same uniform thickness throughout a main part 14a and an extension 14b as shown in Fig. 9. However, strength of magnetic dipole orientation in the extension 14b is differentiated from that in the main part 14a. That is, the magnet 14 is magnetized to have a strong orientation part S and weak orientation part W. The orientation is stronger in the extension 14b than in the main part 14a, thereby generating the induction voltage e to counteract to the reactance voltage. It is also possible to change strength of magnetization of the magnet to have strong magnetization and weak magnetization.

(Sixth Embodiment)

In the sixth embodiment, a magnet 15 is shaped to have a main part 15a and an extension 15b. That is, the extension 15b is thinned at its end opposite the main part 15a, and the orientation is strengthened in the extension.

(Seventh Embodiment)

In the case of such a magnet 14 having the uniform thickness as in the fifth embodiment (Fig. 9), it may be difficult to distinguish the extension 14b from the main part

14a from its outer configuration. The magnet 14 is likely to be assembled to the housing 7 in reverse. Further, the commutation performance cannot be improved, if the magnet 14 is displaced from its right position in the assembling process.

5 Therefore, in the seventh embodiment, a recess or concavity 16 is formed on the arcuate magnet 14 to be visible externally as shown in Fig. 11. It is preferably provided at a position displaced from the central line (circumferential center) L of the magnet within the range of the main part 14a.

10 This recess 16 can be formed in the magnet molding process. It is preferred that the recess 16 is provided on the corner where the axial side end surface and the planar outer peripheral surface cross, so that it may be recognized externally even after the assembling process. The recess 16 may be replaced

15 with a protrusion or convexity. The recess 16 or protrusion should be sized and positioned not to influence the magnetic flux amount of the magnet 14 nor lessen the mechanical strength.

(Eighth Embodiment)

In the eighth embodiment, a colored marking 17 is provided by printing or the like as shown in Fig. 12. The marking 17

20 is provided on the circumferential end of the side end surface of the magnet 14.

In the foregoing embodiments, the extensions may be formed into different shapes as long as the commutation characteristics is generally linearized. For instance, the

25 extensions may be a shape so that the current may change smoothly, that is, the commutation may be effected in a sine-wave

characteristics, at the start and end of the commutation. The recess, protrusion and marking may also provided on the magnets used in the first to fourth embodiments (Figs. 1 to 8).

Further modifications and alterations are also possible
5 without departing from the spirit of the invention.